AGS STUDIES REPORT NUMBER 110

Date 4/13/78 Time 1630-1930 Experimenters F. Pedersen, E. Raka, E. Gill

Subject Longitudinal Impedance Measurements III

OBSERVATIONS AND CONCLUSION

Introduction

It was decided to attempt to measure the impedance at ≈ 7 GeV by again exciting the coupled bunch modes around h = 13, 14. Although this is below the transition energy of ≈ 8 GeV the impedance is still expected to be inductive in the range of 10-15 Ω since the space charge contribution would not cancel the inductive wall Z until one reaches ≈ 5 GeV. At 7 GeV the bunch width and phase oscillation frequencies were expected to be about the same as for the 27.4 GeV case of run II. Because of the lower energy one does not have to extract the beam and a higher intensity could be used in order to increase the amount of incoherent dipole frequency shift.

Procedure

A flattop at ≈ 7 GeV was introduced with time comb "J" for about 1 sec. The peak-to-peak radial ripple (synchronization loop open) was less than 0.5 mm at a β_{min}. After adjusting the flattop slope the frequency synchronization loop was closed satisfactorily. However, it was immediately apparent that there was troublesome momentum jitter from pulse-to-pulse. Some effort was made to reduce this but no significant improvement was achieved. It was decided to continue with the resonance excitation anyway.

Observations

The momentum jitter was generally correlated with Gauss clock fluctuations and resulted in radial excursions when the synchronization loop was closed. These were as large as 1.5 cm peak-to-peak at a β_{min}. This translates into a $\Delta B/B \approx \pm 0.14\%$ at a Gauss clock reading of ≈ 13,420 and energy ≈ 6.84 BeV.

It was possible to stimulate the dipole resonance at h = 13 but the radial jitter though generally less than the maximum value cited above made a precise determination impossible. Actually the observed dipole excitation frequencies varied from 221 to 233 cycles, a result that was not understood at the time. Although the quadrupole mode at h = 13 was also excited (lower sideband) the variation again was so great that no precise determination could be made.

A naturally growing dipole mode at n = 5 was observed and stimulated at the lower sideband of h = 7. At high intensity (8.5×10^{12}) this mode had a measured growth rate of 5.75 sec^{-1}, i.e. 0.17 sec e folding time. It is the main unstable mode present at this energy.

Discussion

The principle cause of a variation in the coherent dipole frequency is expected to be due to variations in $\eta = 1/\gamma_{tr}^2 - 1/\gamma^2$ with momentum since at 6.84 GeV $\eta \approx 0.00499$. Assuming γ_{tr} constant one would obtain a $d\eta/\eta \approx \pm 2\%$ for the $\pm \approx 0.36\%$ momentum variations observed. However γ_{tr} is also a function of γ and the machine nonlinearities. One has $\Delta E_{trans} = -[1.5 + \alpha_2] E_{trans} \Delta p/p$ where α_2 depends upon the nonlinearities.[1] It has been calculated to be ≈ 2.5 for the AGS but not measured. For this value of α_2 one obtains an additional ± 8% variation in η of the same sign as the ± 2% change for a total variation of ± 10%. Since $f_d \sim \sqrt{\eta}$ this would represent a ± 11 cycle range for the coherent dipole frequency. It is this fact, which was overlooked initially, that caused the large observed f_d variations and made a precise determination impossible.

This suggests two methods of measuring α_2. If one had a momentum variation an order of magnitude smaller he could change the radius by changing the synchronization frequency and measure f_d as a function of Δr or $\Delta\gamma$ and use this to calculate $\Delta\eta$ and hence α_2. If the momentum fluctuations are still of the order of 0.1% one could power sextupoles to change the machine nonlinearity so that α_2 would change sign and eventually make $\Delta E_{tr} = 2\ E_{tr}\ \Delta p/p$. This would then cancel the direct γ variation of η and one would observe no change in f_d with momentum or radius. One then obtains α_2 from the magnitude of sextupole (zero theta) excitation. Also one could, in principle, do the impedance measurement under either of these two conditions.

The next run should probably be below 5 GeV so that the space charge impedance dominates but not so low that one is below the Landau damping threshold at maximum intensity. Somewhere between 3.5 and 4 GeV should be tried but first some further effort in understanding and correcting the source of momentum variation must be made.

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1. E.C. Raka, Betatron Frequency Jump at Transition in The Brookhaven AGS, AGS Division Internal Report 70-1 (1970).